

Cities under the Mediterranean

The Mediterranean is a sea uniquely rich in old submerged, but well-preserved ruins. Hundreds represent the remains of ancient Roman harbors, coastal towns, and villages. Some sites reflect all archaeological periods of the last 5,000 years, and a few sites are even older. To begin our tour of this drowned land, let us first see why so many coastal centers were built, then how they sank, and why their remains survived so well beneath this sea.

There were good reasons why the ancients built so profusely on Mediterranean shores. With the nearby Red Sea and Arabian Gulf, the eastern Mediterranean emerged as one of the chief cradles of seafaring commerce when Neolithic village communities evolved into trading Bronze Age powers about 3000 BC. When the Bronze Age began, the Mediterranean already abounded in anchorages produced by climatic change over the previous 15,000 years or so. During the late Ice Age, when the sea level lay as much as 100 meters (330ft) lower than now and the climate was locally wetter, rivers bordering the Mediterranean had cut deep valleys across what is now the continental shelf. As the sea rose to its present level its waters invaded countless valleys and inlets. Thus, at the beginning of the Bronze Age, every coast was studded with perfect natural harbors.

On much of the Mediterranean coast this sailors' heaven did not last long. As sea levels stabilized, the sea's erosive force and sediments supplied by the rivers and winds between them began to straighten coastlines. The process happened faster to a gently shelving coast with small indentations than to a steep, deeply indented one.

Mediterranean coasts are very unequal in these respects. The southern and eastern shores are the straightest and have the fewest inshore and offshore islands. They also lack big rivers except for the Nile. But they do have hundreds of intermittent streams bringing down plenty of sediment, especially sand from the Sahara and other deserts. The result is that, today, there are few good harbors from Tangier to Beirut.

The northern Mediterranean shore, from Gibraltar to Turkey, varies from stretch to stretch. In general, though, it is steeper and more deeply indented than the southern and eastern shore. Many sizable rivers of southern Europe and Asia Minor enter the sea along this coast. But the continental shelf is so narrow that most sediments washed in by these rivers plunge into deep water, or build only small deltas. Unlike the low southern coasts, the northern coasts have changed little since Bronze Age times, and still retain deep bays, steep headlands, and numerous islands. In many coastal sites local erosion or silting has been too slight to alter the topography much. The major exceptions are on the Rhône, Po, and Menderes deltas, where the coastline has

advanced many kilometers in the last few thousand years.

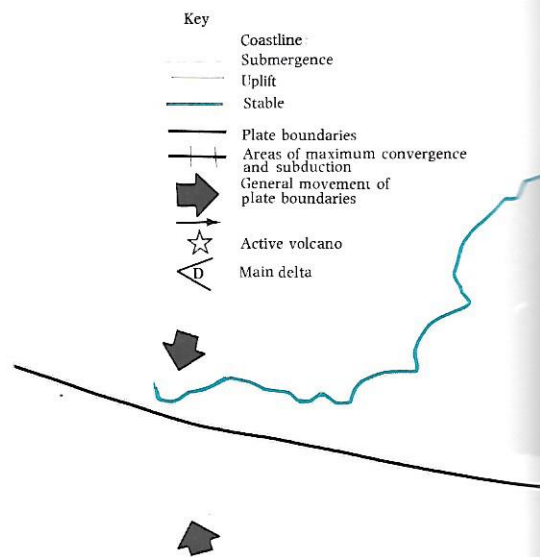
These coastline changes themselves are not enough to explain how scores of Bronze Age and later sites became drowned. By the beginning of the Bronze Age the rise in sea level that had followed the end of the last Ice Age glaciation had just about stopped, and the level has fluctuated little since then (pp. 132–37). Indeed, average Mediterranean sea level relative to coastal land has varied by no more than plus or minus half a meter (1½ft) in the last 5,000 years.

But this is only the general picture. Some parts of the coast have been sharply uplifted and others depressed. Whole harbors have collapsed almost intact into the water in Italy, Greece, Turkey, and Cyprus. General processes of submergence are dealt with on pages 132–37; but here we must take a brief look at the forces that make much of the Mediterranean coast so unstable — the same forces indeed that help to give the north and south coasts their different characters. These forces are the massive earth movements explained by the theory of plate tectonics.

This theory holds that Africa, together with part of the floor of the Mediterranean, is moving north toward Europe at about 2.5 centimeters (1in) a year. Arabia and Turkey are smaller continental fragments that are moving in other directions. Over many million years, Corsica, Sardinia, and Italy have rotated counterclockwise and swung away from France, opening up the Tyrrhenian Sea and narrowing the Adriatic. At the same time, the eastern floor of the Mediterranean has been compressed and foreshortened.

Even in the short span of time since civilization began, earth movements have sparked off volcanic eruptions and also earthquakes that have moved some stretches of coast up, down, or both. As you would expect, the regions of fastest relative plate movements are the regions where earthquakes happen most often. Thus the coasts of Algeria, Italy, Greece, the Aegean, Cyprus, Lebanon, and Israel are much more unstable than others. Research has shown that areas of downward movement are quite widespread, with subsidence of 1–2 meters (3–6ft) in 2,000 years. Areas of uplift have proved to be much more restricted, although movement here may be more rapid: as much as 10 meters (33ft) in 2,000 years. Thus the actual number of submerged cities is far greater than the number of uplifted cities. When you add to the number of cities submerged by earthquakes those submerged by the subsidence of major deltas, and those where harbor remains are under water because they were built there, it becomes clear why the Mediterranean has such a large tally of subsea ruins.

What still needs explaining is why so



Above, right: Map of the Mediterranean basin, showing the main geological fault-lines, and the directions in which the various blocks of the earth's crust are moving.

Right: The six main types of natural anchorage identified by geographers. Upper left: a natural embayment, as seen at Sydney, and San Francisco. Upper center: a river estuary, as seen at London, and New York. Upper right: shelter behind an offshore island, as used by early mariners (see pp 166-67). Lower left: bays behind a headland, as used at the Piraeus, and Syracuse. Lower center: shelter in the lee of a promontory; this is effective only during certain wind directions, and so permanent ports do not develop. Lower right: a delta, as seen at Marseilles, New Orleans, and Cairo.

many structures are so well preserved. In many parts of the world you would not expect a broken stone wall in shallow water to remain recognizable after a few years, let alone after 2,000. However, the Mediterranean is almost like an embalming fluid for ancient harbors. With a few exceptions there is relatively little rainfall and river runoff to cover ruins with sediments; there is no reef-building coral to encrust the ruins; seaweeds seldom grow densely enough to conceal them; and the tidal range is too small to set up erosive tidal currents or to expose ruins to foreshore looting. Although the weather is rougher than many northerners, suppose, storms rarely unleash waves large enough to smash stone buildings made without mortar or cement. Finally, earth movements in this area have drowned hundreds of coastal towns up to 5 meters (16ft) deep — deep enough to escape the force of most storm waves.

A Bronze Age puzzle

The tiny rocky island of Pavlo Petri lies at the northern end of the sandy bay of Vatika in the extreme southeast of mainland Greece. A Bronze Age ship sailing from Crete to mainland Greece would have navigated by line of sight to the islands of Antikythera and Kythera. There she would have hugged the shore to the northern end of the island, before cutting across a strait into the Bay of Vatika. Whichever way she went the ship would then have had to round a headland – either Onugnathos (in order to sail to the fertile lands in the Gulf of Lakonia) or Malea (in order to sail up the southeast mainland coast). For ships on either trip the Bay of Vatika afforded valuable shelter.

In 1967 I discovered Bronze Age remains on the sea floor between the island of Pavlo Petri and the mainland. Next year these were surveyed in great detail by a team of divers from Cambridge University. The oldest remains, dating from before 2000 BC, proved to lie on the island itself; most of the site beneath the sea was of Mycenaean Age (1500–1000 BC). Much of its uncedmented stone walls remained surprisingly intact. Presumably the town had been



Above: The Aegean Sea, showing the Bronze Age sites mentioned on these pages.

Far left: A line of curbstones on the seabed at Pavlo Petri, clearly marking the course of a street.

Left: A cist-grave on the seabed at Pavlo Petri. Opposite: A plan of the submerged Mycenaean settlement at Pavlo Petri on the southeastern tip of Greece. The main street of the village can be seen running parallel to the coast, with several lanes at right angles to it.

covered by earth and sand after people abandoned it during submergence, and then sank gradually beneath the sea. Waves had merely winnowed away the sand, revealing the patterns of walls, streets, houses, and graves on the sea floor.

An exhaustive search of the underwater site revealed no buildings of any kind more than 3 meters (10ft) down. Thus the ancient shoreline must have been 3–4 meters (10–13ft) below present sea level. Two main streets were mapped, and 15 complete house foundations, each typically revealing

5–10 nearly rectangular rooms. The search also revealed 37 stone, box-like tombs known as cist graves. A major goal of the 1968 survey was to discover the harbor and dockside. It is obvious that the ships would have gained the best shelter in the bay enclosed by Pavlo Petri and the ridge that then connected it to the mainland, but no special buildings of any kind were found. The houses and streets just dwindle away at the ancient waterline.

This illustrates one of the big puzzles of underwater archaeology in the Mediterra-

nean. By 2000 BC many river mouths and small bays had silted up; thus you would expect that by then people had learned to construct artificial harbors. By 1000 BC they surely must have done so. Yet finds of Bronze Age artificial harbors are as scarce as hen's teeth. Archaeologists have mapped or excavated many Bronze Age sites on the coasts of mainland Greece, the Aegean islands, Crete, southern Turkey, Cyprus, Lebanon, Syria, and Israel, but few show signs of man-made harbor structures. Pavlo Petri and nearby Asopos, Mochlos in eastern

Crete, and Aghios Kosmas (near Athens Airport) are among sites with Bronze Age remains now under water. But most of these relics are those of buildings originally erected on land, albeit near or on the beach. The exceptions are some rock-cut features or sculpted reefs that we shall come to in the next two pages.

Let us look now more closely at the puzzle posed by the lack of Bronze Age harbors in what was plainly a flourishing maritime world. Pottery found at coastal sites all around the eastern Mediterranean testifies to active trading between places in what are now Greece, Crete, Turkey, Syria, Lebanon, Israel, and Egypt. The fabulous ship frescoes from Akrotiri on the Aegean island of Thira show sophisticated ships and two coastal towns with houses of several stories. Yet a close examination of the frescoes shows no special waterline features that could indicate harbor works.

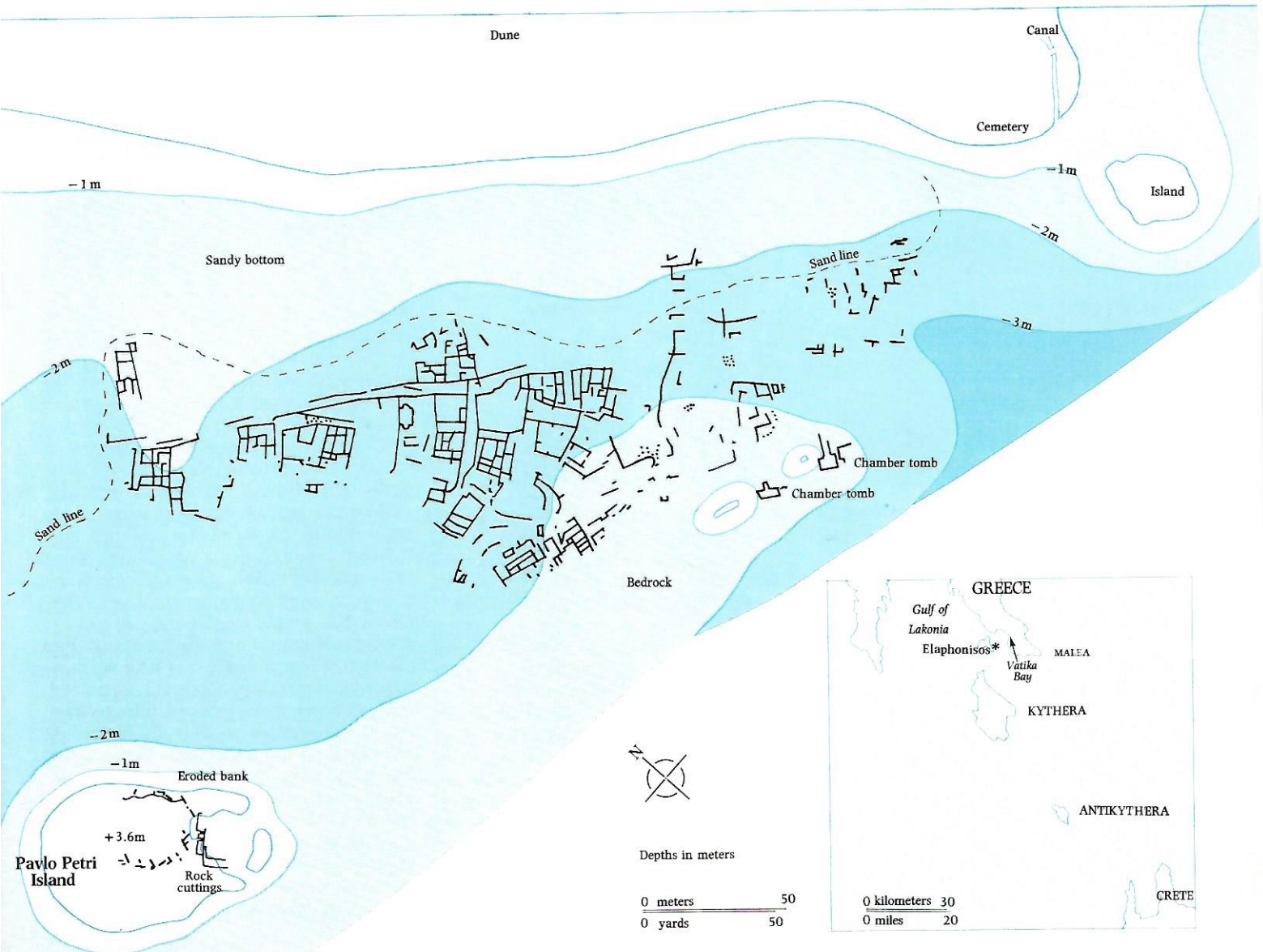
To my knowledge, divers or snorkelers have swum and searched around more than a dozen Bronze Age sites in the eastern Mediterranean without producing a single item suggestive of an artificial harbor. In

several cases, parts of town walls or pieces of pottery were found in the water. Rarely, there were slim hints of something more: Neve Yam, in Israel, has submerged walls dating from 4500 BC. At Amnisos in Crete a very solid wall extends just below the water but stops abruptly in the surf line, suggesting perhaps a jetty for small boats. The landward side of Tel Nami, a small headland on the coast of Israel, seems to have been built up with a massive wall, but that could have been as much a city defense as a dockside, and there are no signs of artificial breakwaters.

Scholars have often argued that boats were simply dragged up on the beach. This makes sense for military vessels with large crews and oarsmen, especially since a skilled strategic commander would tend to exploit natural shores rather than main ports. But a crew of 3-5 men could scarcely have dragged a heavily laden commercial vessel onto a beach. They could have moored such a ship to the shore with a stern anchor to hold her secure and prevent broaching, but that would have made unloading a cargo a tiresome job of running

down a steep gangplank from the bow, or heaving loads onto donkeys, carts, or men standing in the water. Surely the major entrepôts would have had jetties of wood or stone, and breakwaters to guarantee calm water. Wooden jetties — if they existed — would have required frequent rebuilding, and we can hardly expect any traces of such structures to have survived. Slightly more solid jetties of wooden palisades filled with stones would also have left little trace, since the piles of stones would have spread out and become almost indistinguishable from natural rocks. However, Asine near Nauplion in Greece has a ridge of stones suggestive of such a structure.

Thus we are forced to conclude that the Bronze Age mariners of the Aegean, Cyprus, and Israel used headlands, inshore islands, river mouths, and bays more or less as nature had shaped them. Diving investigations have proved almost beyond doubt that even most towns that were certainly trading centers possessed neither man-made harbor basins nor breakwaters. In places, though, a revolutionary change was about to begin, as we shall now see.



Gigantic harbors in the Levant

The Mediterranean's early sailors used natural anchorages so good that these needed no embellishment. Then, on eastern coasts, changed conditions led to the first artificial harbor works.

We have seen that the inlets used by early Bronze Age shipping largely silted up in the next 2,000 years. This was particularly true on the eastern Mediterranean, or Levantine, coast from the mouth of the Orontes in southern Turkey to the mouth of the Nile in Egypt. This shoreline has been smoothed into an immense curve, with only small kinks, like the Bay of Haifa. There are now no good natural harbors on the whole of this 800-kilometer (500-mi) stretch. The Bronze Age sailors of this coast suffered the unpleasant experience of finding that their ships were gradually and remorselessly excluded from river after river, bay after bay, as sand and mud straightened out the shore. But, meanwhile, shipwrights were building progressively larger vessels — too big to use what creeks survived.

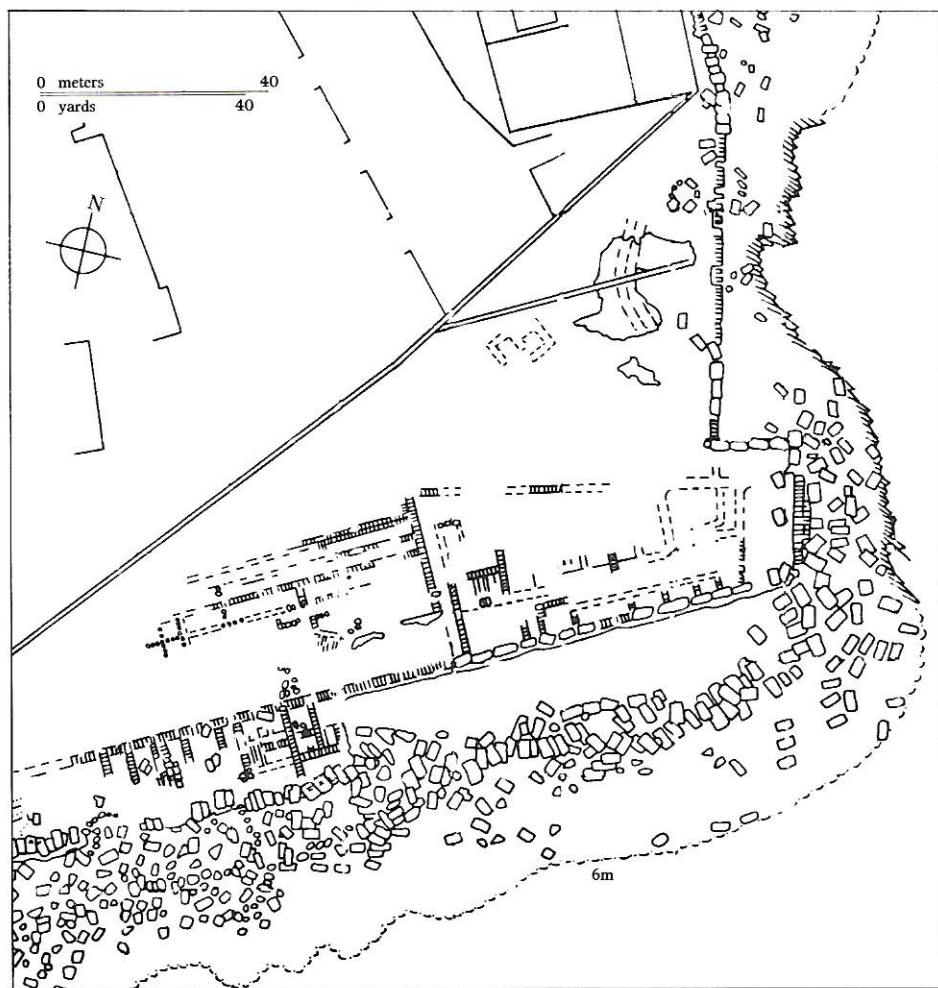
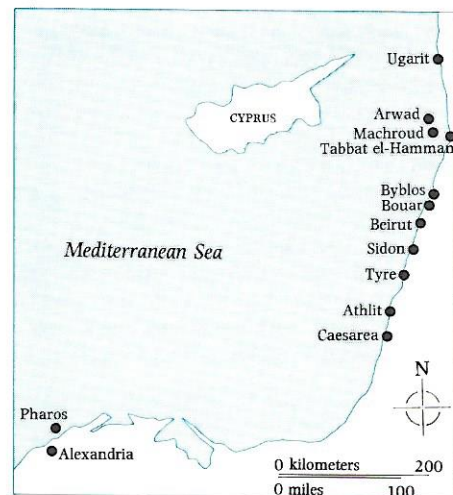
It is not surprising, then, that Phoenician and Egyptian seafarers developed a new approach to sheltering and protecting their ships. In this they were helped by natural offshore sandstone formations. These had their origins in long lines of enormous sand dunes that formed on the ancient sea coast, beyond and below the present position of

the shore. In time calcium carbonate and other minerals derived from groundwater cemented the sand particles together to form a soft kind of sandstone. Streams and small rivers cut their way through the hardened dune ridges, and swamps formed between them. The ridges are not exactly parallel to each other, or to the shore, since they are influenced by the underlying topography and neighboring mountain ranges. Consequently the form of the modern shore and shallow water zone largely depend on the angle at which the sandstone ridges meet the waterline.

In places the ridges form low, continuous hills facing the sea. Elsewhere they jut out as stubby wave-girt peninsulas. Yet other ridges form offshore reefs and islets parallel to the main line of the coast. Some islets are quite large. Arwad, in the north is hundreds of meters long. With Tyre, near the center of the Levantine coast, and Pharos, near Alexandria, Arwad was one of three Levantine islands inhabited in Bronze Age times. Much of what we know about them comes from the collective work of three archaeologists: Antoine Poidebard and Gaston Jondet, active before World War II, and Honor Frost, working in the 1960s. Dating the ancient structures found on and around the islands is difficult, but no one disputes that such structures exist and are old.

Throughout the early Bronze Age sailors must have come to learn a lot about these dangerous offshore ridges and reefs. For instance, in winter storms they would have seen the long line of white breakers about 1 kilometer (0.6mi) offshore — where the

Below: The eastern Mediterranean, showing the Levantine harbors mentioned in the text. Below, left: A detailed map of some of the submerged masonry discovered off the island of Arwad.



open sea broke over the submerged reefs. Surprised by a storm, or awaiting a favorable wind, early ships with a shallow draft must have sheltered often behind these reefs and small islands. Then, as ships were gradually forced from the coastal rivers, the sailors must have realized that a little improvement could have turned at least some reefs into havens. We do not know just when this happened. Certainly Arwad was inhabited by 1500 BC. It is reasonable to guess that sailors were increasingly adapting reefs to their needs in the next 500 years. How was it done?

The line of reefs and islets from Arwad to nearby Machroud (both off what is now Syria) shows how. At Arwad, air and underwater surveys reveal that the landward side of the island was quarried and flattened to make a quay, while much of the stone removed by this process went to build a masonry wall on the seaward side. This meant that people could build and quarry storm-proof houses and storerooms on the island. Just how durably they built we may judge from mooring stones cut from solid rock, and sea walls recessed into grooves cut in the bedrock so that the impact of waves would not shift them. Parts of the quays and some masonry courses now are under water, and it seems that the island has sunk at least 1–2 meters (about 3–6ft).

At Machroud, 3 kilometers (2mi) south of Arwad, the dry area suitable for construction is now only 60 meters (200ft) across, but underwater mapping suggests



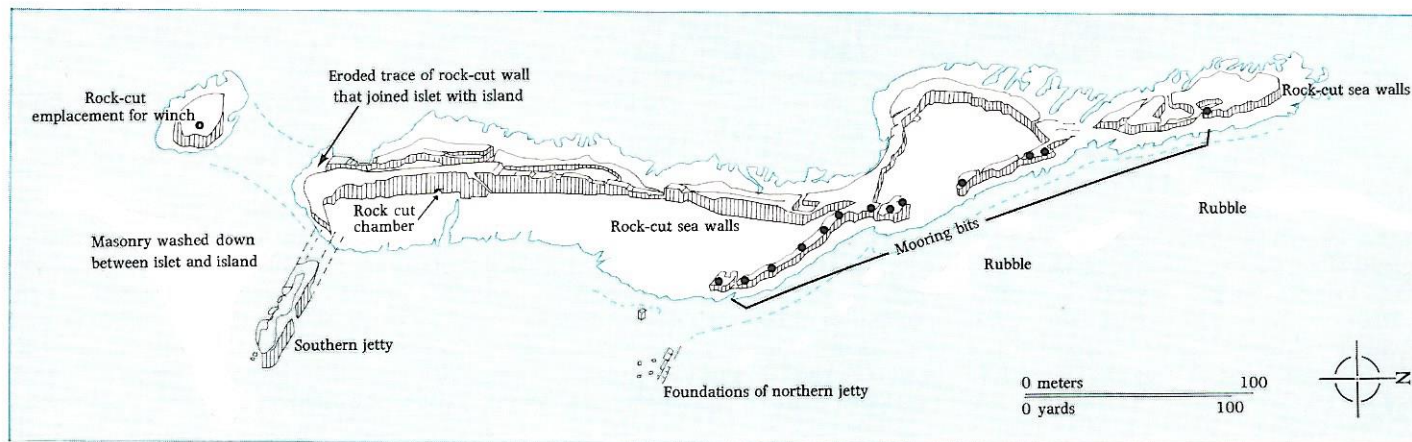
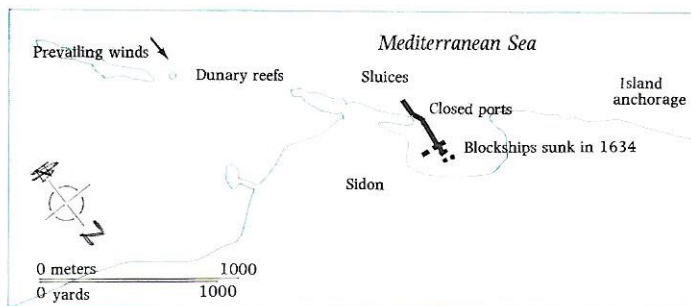
Left: An aerial photograph of Arwad, viewed from the nearby mainland.

Below: An overall map of the ancient harbor installations at Sidon, and a detailed map of the offshore island. Although the bedrock of the island has been extensively cut and refashioned to provide quays and storehouses, this has not impaired the value of the site as a safe anchorage.

never inhabited. The small island known as Pigeon off Magaan Mikhael has some cuttings and stone storage tanks, but no signs of continuous habitation.

Finally, at Pharos, on the seaward side of Alexandria in Egypt, a great submerged protoharbor was reported by Gaston Jondet in 1916. Jondet claimed to have found artificial harbor works along the whole of the reef that runs west for more than 2 kilometers (2.5mi) from Ras al Tin to Abu Bakr. Archaeologists treated his claim with cautious skepticism, and it remains unverified. In view of Honor Frost's more recent discoveries along the Syrian coast the claim is at least plausible.

Some people find it unbelievable that structures as big as these were truly early harbor works. But several factors point to this. First, the linear sandstone reefs off the



that the island has sunk by 6 meters (20ft). Thus the original usable area would have been larger, and quarries and buildings would have stood well clear of the water. Habbes, Abou Ali, and Nussonie – the three islets between Machroud and Arwad – all show signs of quarrying. Assuming that all this reef was 2–5 meters (6–16ft) higher in the middle of the Bronze Age, we can see that systematic quarrying and construction on the outer edge would have provided an enormous sheltered basin between the reef and the mainland, where there are two Bronze Age towns, Amrit and Tabbat Al-Hammam (p. 168).

At Sidon (now in Lebanon) part of the port was formed by a segment of sandstone ridge projecting from the mainland, and part by reinforcing the natural continuation

of the ridge 1 kilometer (0.6mi) to the north. At Tyre, farther south, the main town was built on a reef-island about 700 meters (2,300ft) across, and 500 meters (1,600ft) from the shore. Submerged reefs extending several kilometers to the south seem to have been reinforced to provide shelter for vessels.

As you continue south the islands get smaller and fewer, but all have been intensively worked in a standard manner: the landward side removed, and the seaward side left as a rampart. The Naohlieli-Sigorion group on the Lebanon-Israel border, and the Achzib group farther south, are very similar in this respect. Today, the quarrying is submerged by only about 1 meter (about 3ft), and as the islands are entirely swamped during winter storms, it seems they were

Levantine coast would have suggested useful shapes made still more useful by reinforcement. Second, the reefs' linearity, and the deep water between them and the mainland, would not have suggested the construction of a round or square enclosed harbor basin. Third, in order to afford good shelter, a linear barrier would have had to be long, otherwise incoming waves would have "bent in" from the ends and met behind the barrier, creating a choppy sea. The reef protoharbors must have served a valuable purpose. But the knowledge won in building them and that already gained from making docks and quays on river banks, soon led to the development of true artificial sea harbors. When this happened, the gigantic protoharbors became as extinct as the *Brontosaurus*.

The first true harbors

Just opposite the Syrian reef-island of Machroud lies the tell (mound) of Tabbat Al-Hamman. In 1940 the American archaeologist Robert Braidwood published a survey of the tell and the neighboring shoreline. This showed that people had lived in the area continuously from the dawn of the Bronze Age to the Byzantine period. The beach at Tabbat Al-Hamman revealed a jetty or breakwater made of massive masonry blocks each about as long as a man. The structure is just over 200 meters (650ft) long and about 15 meters (50ft) wide, and its outer end lies in more than 4 meters (13ft) of water. Correlation with the tell dates it to the ninth century BC. As far as we know, this early Iron Age structure is the world's first artificial freestanding sea breakwater, as opposed to the reinforced reefs of the previous millennium.

The breakwater builders at Tabbat Al-Hamman used dressed blocks, but in the deeper and better protected bays of the Aegean and other northern coasts, people found they could make breakwaters by simply piling irregular rubble blocks into the sea. The first known breakwater of this type is at the Aegean island of Delos; old writings help to prove that it was built in the eighth century BC. During the seventh and fifth centuries BC such breakwaters went up all over the Greek world, which included southern Italy, eastern Sicily, southern France, the Black Sea coast, Aegean Asia Minor, most of Cyprus, and the Cyrenaic coast of North Africa.

Besides the one at Delos, fine submerged rubble breakwaters have been mapped by divers at Salamis in Cyprus; Iasos and Cnidos in Asia Minor; Apollonia and Thapsus in North Africa; Syracuse in Sicily, Piraeus in Greece, Vurgunda on the island of Karpathos. Such breakwaters also form a substantial part of hundreds of other harbors of Greek and Roman date. Apart from the south-coast ports of Apollonia and Thapsus, which we shall look at later, these are all northern Mediterranean ports and of bay-headland type. This type gets its name from the type of site selected as ideal—a so-called anvil headland, which afforded two fine sheltered harbors: one on each side of the city.

Bay-headland ports featured more or less steep fortifiable headlands and promontories, flanked by breakwaters, often continuous with the city walls and designed to narrow the entrances of one or more relatively deep bays. The breakwater builders tipped rubble into water as much as 10–15 meters (33–50ft) deep, and used blocks of several cubic meters, weighing up to 50 or even 100 tons. Quarries supplying the stone usually lay close to the harbor, so there was no problem of long-distance transportation.

The most sophisticated complex of this type was Piraeus near Athens. Before this was built, Athenians had beached their ships at Phaleron, the nearest point on the coast



to the city. But in 493 BC they started fortifying the bays on the peninsula of Piraeus. Over the next 50 years they constructed three harbor basins. Each was protected by rubble breakwaters, crowned with masonry walls, roads, and defensive towers. Iron clamps bound the masonry blocks together. Under seaborne attack, defenders could shut out enemy ships by closing the basin entrances with booms or chains. Finally, the whole complex of harbors was connected directly to Athens by defensive walls 8 kilometers (5mi) long.

Within the harbors of Piraeus stood 372 ship sheds with slipways: sloping ramps up which the sailors dragged their trireme warships for storage. Diving and paddling have revealed traces of old slipways and ship sheds at 12 coastal cities elsewhere, but nothing to match the reported complex at Piraeus. Close to each of its slipways stood a storage shed to take a ship's oars, masts, sails, and military equipment; and nearby arsenals held reserve stores for the whole fleet. Unfortunately, later building obscures the slipways at Piraeus, and the only archaeological evidence for them was a glimpse in 1885 when a brief survey was made during building operations. However, we can judge their size and form from the fact that the larger slipways and ship sheds around the Mediterranean seem to have been more or less standardized at 5.5–6.6 meters (18–21ft 8in) wide and 38–47 meters (125–154ft) long. Gradients were 4–12 degrees, sometimes with a central runner or groove for the keel of the ship, and the slipways were roofed to shelter vessels and the craftsmen working on them.

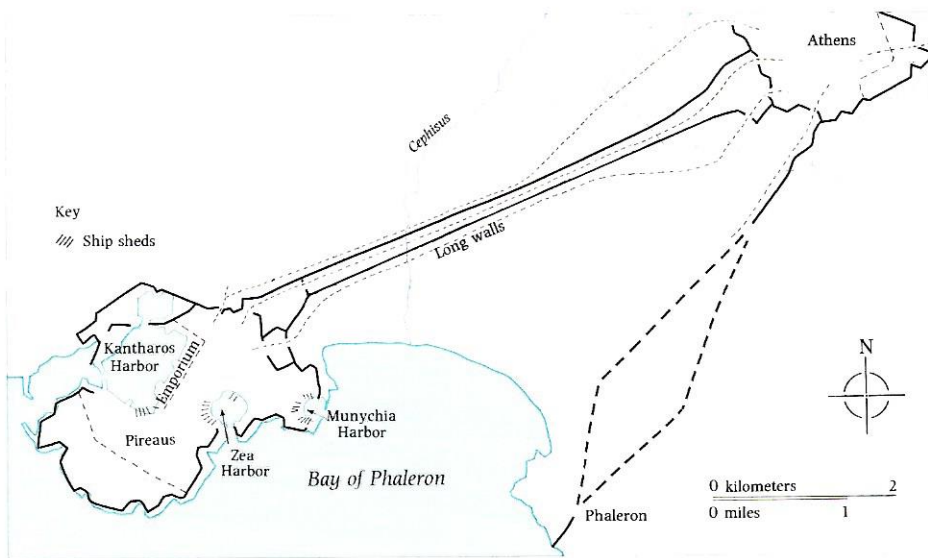
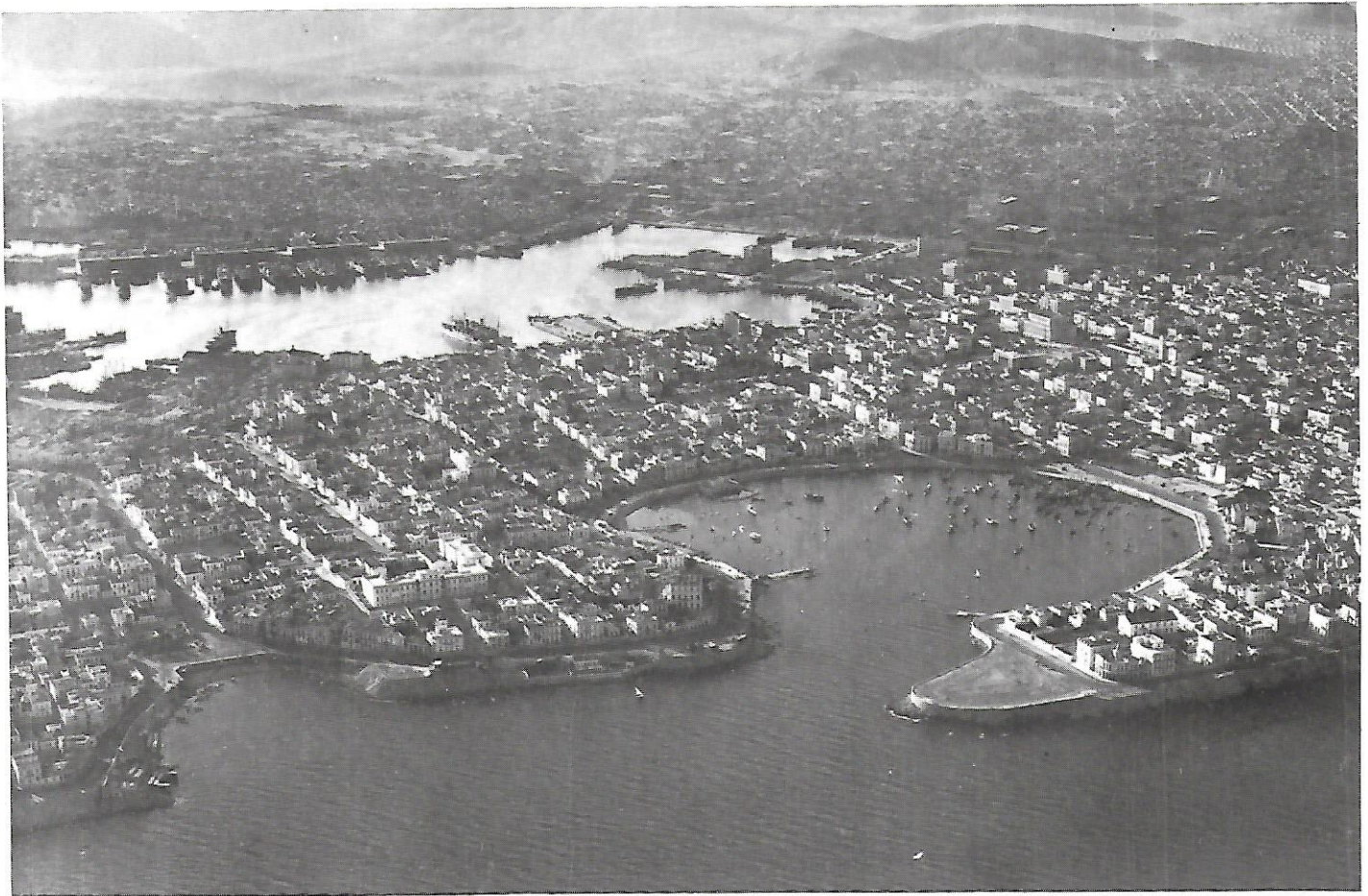
Old Piraeus has been completely built over by a mushrooming modern city and its old harbor basins are modified for big modern craft. Diving archaeologists now have little chance of discovering how its

Above: The Aegean, showing some of the earliest harbors in the area. Places where natural havens were used are distinguished from those where artificial breakwaters were required from the start; in some instances, naturally favoured sites were further improved by the construction of breakwaters. Right: An aerial photograph of part of the Piraeus harbor complex. The circular Zea harbor lies in the foreground, with the head of the Kantharos harbor beyond. The map below shows the full range of natural anchorages available to ancient Athens, together with the fortifications which linked them with the city itself.

slipways, breakwaters, and harbor defenses were constructed. Our knowledge almost all derives from surviving literary descriptions.

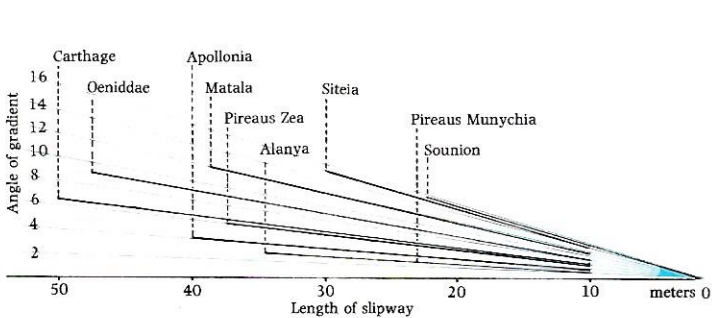
This is not true of Syracuse in Sicily. Modern Syracuse is smaller than its classical predecessor. In 404 BC the dictator Dionysius I ordered the construction of a harbor in the bay north of the inshore island of Ortygia, which was joined to the mainland by a sand spit. The bay is about 700 meters (2,300ft) wide, and most of it is only 5–10 meters (16–33ft) deep. However, a sinuous chasm up to 30 meters (100ft) deep winds its way in through the center of the bay. In 1959, teams of divers found that two submerged rubble breakwaters with embedded pottery fragments extended to the brink of the central trough. The outer foundations stood in more than 10 meters (33ft) of water, and beyond each breakwater a mass of loose building blocks, tiles, marble slabs, and carved blocks had tumbled into the trough. There had obviously been a substantial tower on the end of each breakwater.

The southern harbor at Syracuse was too large to be protected by an artificial breakwater, but provided a perfect shelter for commercial vessels waiting to enter the docks and loading bays of the port proper. This combination of one small defended harbor with a second, larger, and undefended basin is the classic pattern. At



Cnidus in Asia Minor the basin for warships appears to have been shallow and rectangular, while the commercial basin to the south was protected by a rubble breakwater built into very deep water indeed. At both Cnidus and Syracuse the low sandy isthmus joining the headland to the mainland was cut to provide a connecting canal between the two basins.

Building a breakwater from rubble, as the ancient Greeks did, need not be a crude and unsophisticated way of making a wall to withstand wave action. Indeed, rubble breakwaters are the commonest sea defenses built by modern contractors. The stones on the outside, near the waterline, bear the brunt of wave attack, and the fact that there are holes between them, and that the stones can move a bit, helps to dissipate wave energy without sharp impacts or shocks. The lower part of the breakwater and the main core can be built of fairly small stones, while the outer face at the waterline must be made of large blocks. There is every indication that the classical engineers were well aware of this, and used their materials as economically as possible. Provided that the whole mound of stone is stable, road, walls, and towers can be built on top if set back from the seaward slope.



Left: A diagram comparing the lengths and angles of slope of the various ancient warship slipways discovered in recent times around the eastern and central Mediterranean. Considerations of local topography, and of the size of vessel in service, will have been the principle determinants of the various specifications.

The Carthaginians excavate their harbors

While the Greeks planted colonies largely on the northern Mediterranean shores, their Phoenician rivals were building in North Africa, western Sicily, Spain, and parts of Sardinia. Sailing westward from bases in the Levant, Phoenicians beat Greeks in the race for Spain's valuable supply of tin. The direct route to Spain lay between Sicily and what is now northeast Tunisia, then along the coast of what is now Algeria. The Phoenician colonies of Carthage, Utica, and Ruscinona (south of the Sicily Channel) and Motya (to the north) made sure that control of that vital section of the route stayed firmly in Phoenician hands. Founded in 814 BC, Carthage soon came to dominate the western Mediterranean. Like their Phoenician forebears, the Punic (Carthaginian) peoples were renowned for their skilled seamanship, canny trading, and military efficiency, sometimes associated with piracy. This makes it especially interesting to see how harbors and harbor technology helped to support the Carthaginians' seaborne success.

We saw earlier that there were few good natural harbors on the North African coast. Those of Carthage itself were probably entirely man-made. The port stood on a large anvil-shaped headland about 5 kilometers (3mi) across – a shape since made unrecognizable by sediment dumped by the Medjerda River. This has thrust the shoreline west of the city forward by nearly 10 kilometers (6mi). The sheer size of the headland may have dissuaded Carthaginian engineers from making harbors on each side, though they did wall off the isthmus to protect the city against land-based attack.

The harbors of Carthage were not in fact built out into the sea, but dug back into the land. This kind of harbor is called a cothon, and Carthaginians were its chief and maybe only exponents. They built a large cothon at Mahdia, south of Carthage; a small one at Motya, in Sicily; and an even smaller one, just a dock really, at Monastir, near Mahdia. These three and the harbors at Carthage are the only known cothons.

Where did cothon-building come from, and why was it used? Clues lie in the Near East. Besides its reinforced reefs, Bronze Age Tyre may have had a closed harbor next to the city and inside its defenses. A stronger hint of cothon evolution comes from Jezirat Fara'un in the north of the Gulf of Eilat (Israel). This island has an Iron Age harbor, possibly of Bronze Age origin. It is a basin totally enclosed within the island. People made the basin partly by excavation, and partly by building up the seaward edge of a natural depression. Another harbor-building tradition pointing toward the cothon could be the large basins dug into the banks of the Nile as berths where ships could load and unload away from the river current and passing traffic.

Given the Phoenicians' and Carthaginians' ambitions in trade and warfare, it



Above: A view across the cothon at Motya in Sicily. Left: Surveying in progress within the cothon at Mahdia in southern Tunisia. This is the smallest cothon known, and is now partially silted up.

seems that the Carthaginians adapted the concept of the harbor within the city's defenses, and took it to the logical conclusion of digging right back from the coast. This meant that no attacker could try to capture the harbor before attacking the city. Naval security was complete.

Archaeologists have excavated two harbors at Carthage. One was rectangular and about 500×300 meters (1,640×980ft). The other was circular and 330 meters (1,080ft) across, with a central island about 120 meters (390ft) in diameter. The harbors provided space for 200 warships, and their slipways, ship sheds, ships' stores and military stores. In the 1970s the British archaeologist Henry Hurst supervised exploration of the harbor area, and groups of divers led by Bob Yorke and David Davidson, British marine archaeologists, have conducted in-

tensive surveys in the shallow muddy water.

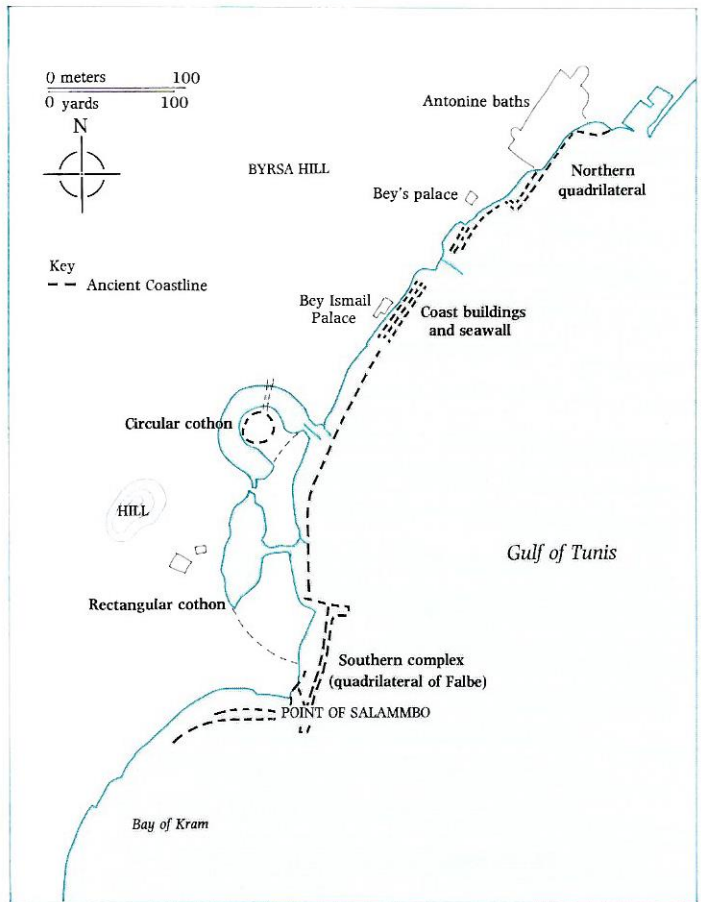
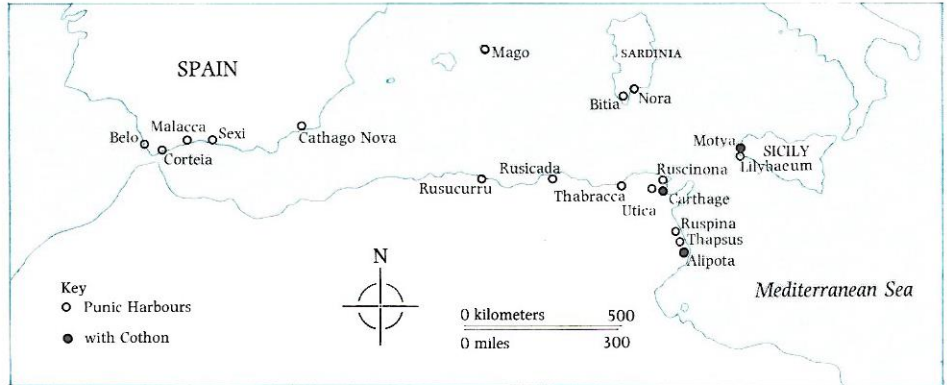
Carthage was destroyed by the Romans in 146 BC so ferociously that no one can be sure of the full function and form of the harbor areas. But aerial photographs have clearly shown submerged structures in the open sea outside the enclosed basins. Also, work in the circular basin and on the island has disproved the notion that the slipways had been cut from stone and laid out like the spokes of a wheel. We now know that the island slipways extended, herringbone fashion, in two parallel rows from a central backbone. Arranged radially, the slipways would have had to taper almost to a point, leaving no room for ships' prows. The average length of the slipways is 50 meters (164ft). Width ranges from 5–7 meters (16–23ft) and the gradient is 6.5 degrees.

The beds of the slips seem to have been lined with heavy timber, while masonry pillars probably held up a wooden roof.

Divers pumping mud from the circular basin have revealed a series of pier foundations. These seem to have supported a bridge or causeway joining the island to the shore. Their level suggests that the city has sunk about 1.5 meters (5ft) since Roman times. In the open sea, Yorke, Davidson, and John Little (another archaeologist from Britain) have mapped a complex pattern of moles and breakwaters, some of shuttered concrete, some of loose rubble blocks. The concrete structures are probably Roman, but those made of rubble could conceivably be Carthaginian. These finds suggest that the entrance to the rectangular cothon basin probably lay just inside the southern entrance to the outer harbor, in the shelter of the southeast mole.

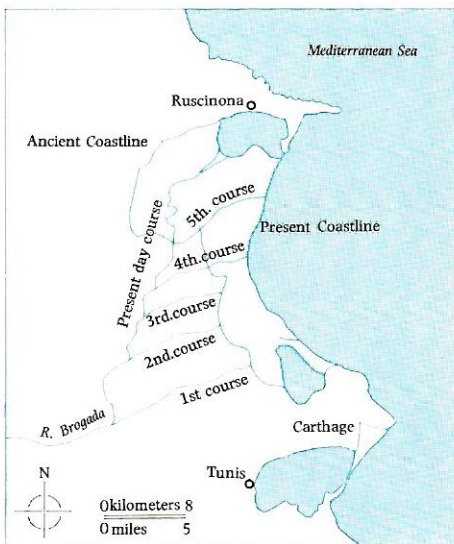
The cothon at Mahdia is easier to understand than those at Carthage. It is a simple rectangle, 147x73 meters (482x240ft) and cut from solid rock. From near one corner a short straight channel leads out into the sea. Along the sides, lumps of stone were left projecting from the quays as mooring bollards. This superbly simple but effective harbor is now partly blocked by sand, but fishing boats still use it.

About 40 ancient ports stand on the North African coast between the Strait of Gibraltar and the Tunisian border with Libya. Most would have been of Punic foundation, although the submerged remains found today are mainly Roman. Divers have discovered plenty of rubble moles and breakwaters, but no cothons. It seems that the cothon experiment involved only Carthage and the area around. Much later, Rome's vast Trajan harbor and part of the Claudian harbor were dug out of the alluvial delta of the Tiber (p. 172). But these were large open basins, quite separate from the Carthaginian tradition of closed military ports. Thus, for all its planned impregnability, the cothon started no trend.



Below, left: The situation of the peninsula on which the Punic city of Carthage stood has changed since classical times because the bay to the north has silted up. But within the city, it is still possible to identify the two enclosed harbors, together with various maritime structures that are now submerged (right). The view across the round cothon (below) shows how shallow it has become, and how the surroundings have been built over in recent years.

Top: The western Mediterranean, showing the principal Punic cities, all of which lay on the coast.



Technical advances under the Romans

Between 100 BC and AD 100 the Romans refurbished and expanded most Mediterranean harbor constructions of previous periods, and founded many new harbors on previously inaccessible coasts. This engineering and architectural achievement was so complete that almost every old harbor that divers try to survey is dominated by Roman constructions. Earlier remains have to be searched for under the relatively much larger Roman structures; newer ones are usually feeble adaptations or modifications of Roman grandeur.

Most Roman harbors featured large rubble breakwaters that differed from their predecessors only in scale. However, there were also a number of major technical innovations. These included shuttered concrete that would set under water; arched breakwaters or moles to allow water circulation and prevent silting; extensive building of stone lighthouses; masonry bonded by multiple keys between every block; and a mastery of design that enabled engineers to construct the largest harbors on straight, exposed coasts lacking natural advantages.

Let us start with the rubble breakwaters. In 1966 divers found the largest breakwater of all off the site of Thapsus in eastern Tunisia. The breakwater extends seaward

of Judea. The coast here was originally straight, although one or two small creeks enter the sea nearby. Architects designed city and harbor as a unit, starting with the drainage and sewerage system. The two breakwaters enclosed a semicircular basin more than 300 meters (980ft) across, with its entrance on the north side, away from the movement of sand along the beach, and protected from the direct onslaught of the dominant west winds. On each side of the entrance three huge statues crowned columns standing in the water. At least one of these monuments probably served as a lighthouse.

Divers have mapped underwater Caesarea intensively, to try to settle a lively controversy as to whether or not its buildings have sunk. In fact most of the shore buildings now stand at the levels for which they were built, or have been slightly uplifted. They include a magnificent fish tank, storehouses, a large sluice gate for seawater, and a sewer. But much of the Herodian rubble breakwater is submerged. Archaeologists could not be sure that it had been built in water of the present depth: 5–10 meters (16–33ft). Accordingly, in the 1960s and 1970s three teams made exploratory dives with some excavation. The organizers were Ed Link, an American pioneer in saturation diving, in the early 1960s, the Israel Undersea Exploration Society in the late 1960s, and the University of Haifa and the Israel Geological Survey, which combined to produce a detailed survey in 1976.

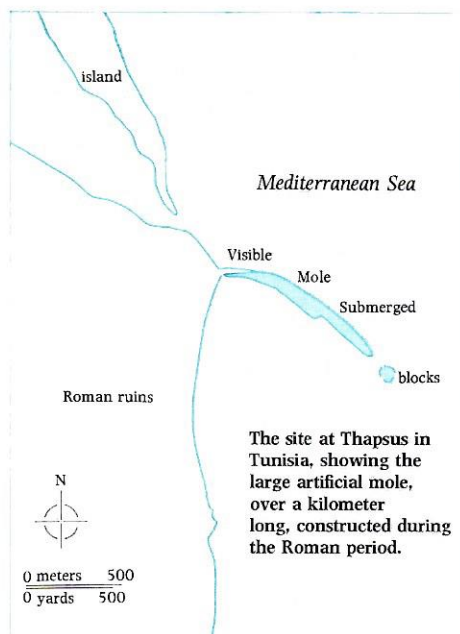
In this last survey, divers cleared away sediments with propwashes – powerful water jets produced by downwash of a ship's propeller. They found several submerged quay surfaces and structures of carefully laid stones on the inner side of the breakwater. These all indicated submergence by 4.5–5.0 meters (15–16½ft). There were also mysterious blocks of masonry or concrete with rectangular recesses, perhaps designed to take wooden beams (an earlier survey had found blocks of stone held together with lead dowels). While the divers worked under water, a launch equipped with an echo sounder and precision navigation equipment generated a detailed bathymetric map of the site. This map plainly reveals the layout of the collapsed breakwater, and how waves have dispersed it.

But the outstanding discovery was the harbor's bisection by a discontinuity, or geological fault. Seaward of that line the breakwater and quays are submerged; landward of that line they remain undisplaced, or are even slightly uplifted. In the late 1970s geological borings confirmed the offset of underlying strata of rock, indicating that the movement is probably due to an active fault.

Other Roman harbors massively built on economically or militarily important sites with few natural advantages include Soli Pompeiopolis in southern Turkey, Seleucia

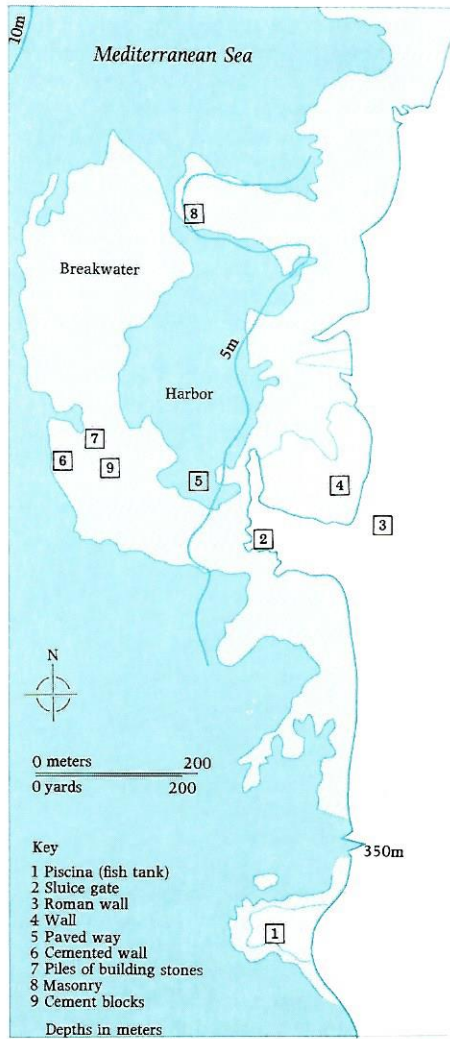
Pieria on the border of Turkey and Syria, Leptis Magna in Libya, and the Claudian and Trajan harbors at Ostia in Italy. In some cases the Romans undertook truly enormous engineering works to ensure that nature did not undermine them. For instance, at Seleucia Pieria they tunneled under a mountain to divert a steep river carrying sand and pebbles liable to make the harbor silt up. They were not always that careful. Thus they failed to take adequate precautions at Leptis Magna, and the harbor there filled up with sand almost before it could be used.

The most intensively developed series of ports in the Roman world were, not surprisingly, north and south of Rome, from Centumcellae to the Bay of Naples. On this stretch of about 200 kilometers (125mi), 20 major ports catered for the military, commercial, and recreational needs of the hub of the empire. In modern terms this was a blend of Rotterdam, Portsmouth, and the Côte d'Azur. The principal military basin was at Misenum, where divers have surveyed a breakwater of rectangular concrete blocks. Nearby, at Puteoli, stood a famous arched breakwater that survived until the first year of the twentieth century, only to be covered by rubble for a modern harbor.



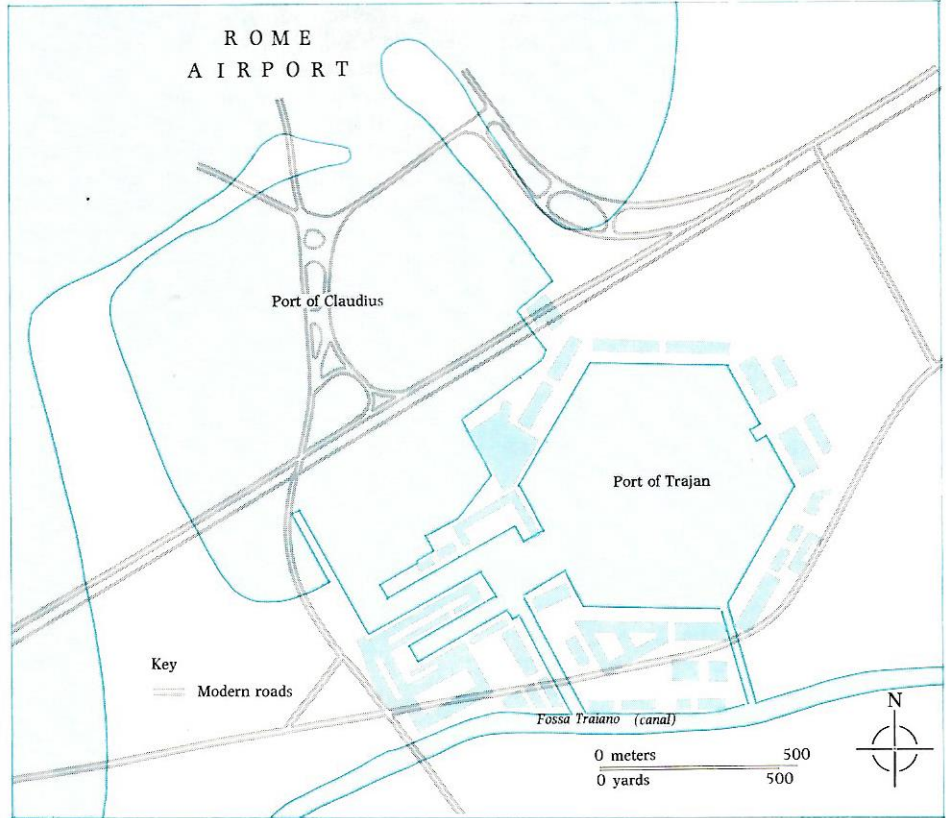
for 1 kilometer (0.6mi) in more than 10 meters (33ft) of water, and is 100 meters (330ft) wide at the broadest part. Calculations of the volume of stone in this colossal construction suggest that the Romans never actually finished it, since the volume seems insufficient to have raised the whole length above water. However, the structure may have sunk as its great weight compacted the seafloor.

At Caesarea Maritima on the Israeli coast lie the remains of a large port dating from soon after 25 BC. It was built with Roman assistance by Herod the Great, king



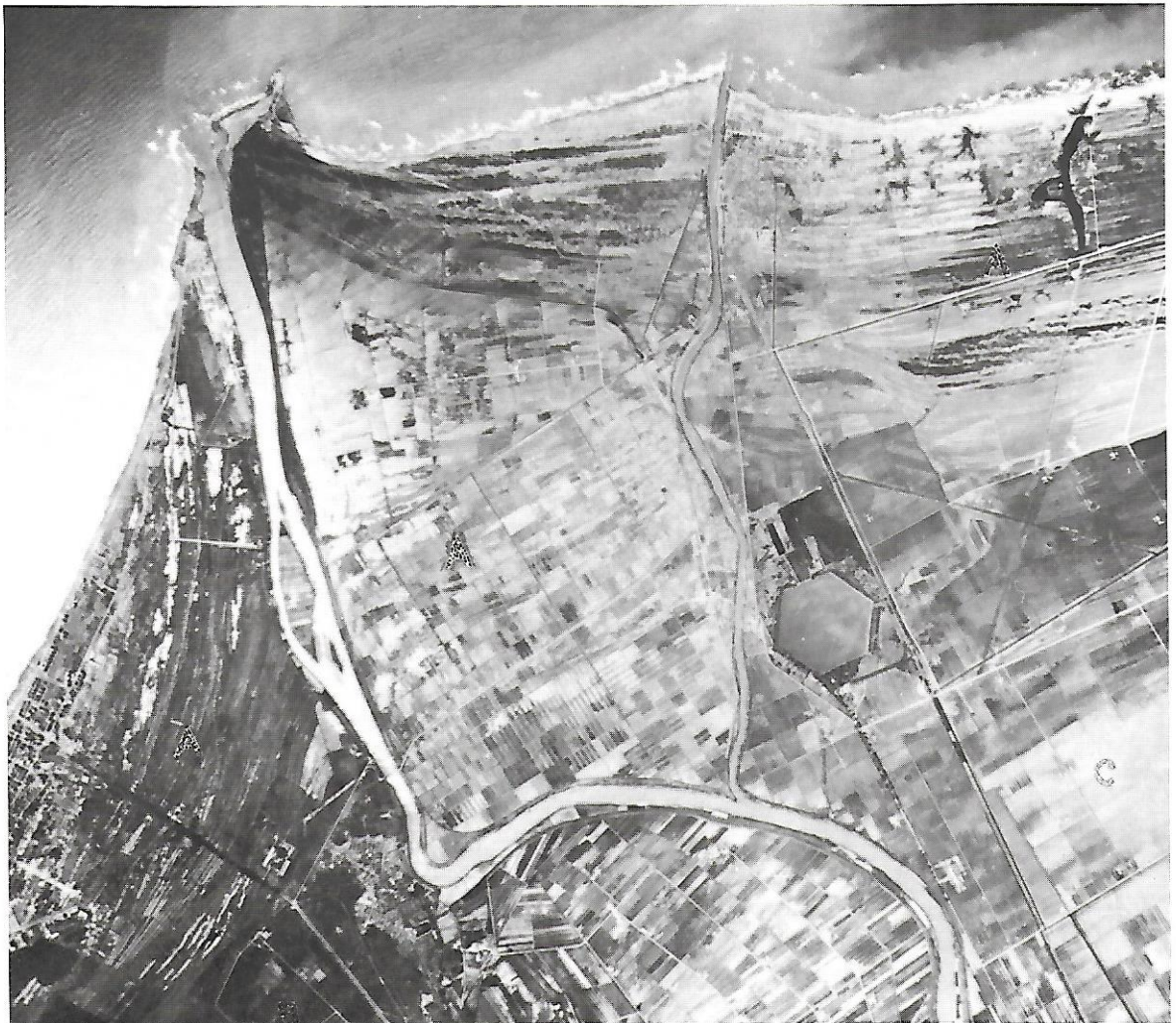
Dotted along the shore lay pleasure beaches with villas and palaces on concrete platforms jutting out into the sea. Many such dwellings had marine fish tanks, recently rediscovered and mapped by paddling and diving archaeologists.

The chief trading port of the empire was Ostia, near the city of Rome. To Ostia each year came countless shiploads of grain from North Africa. Rome itself depended completely upon this lifeline. The earliest harbor at Ostia stood on the Tiber River where it curved just before entering the sea. As the volume of trade grew, Rome needed a larger basin, and during the reign of the Emperor Claudius (AD 41–54) workers raised breakwaters to enclose a huge area just north of the river mouth. But by then sediments dumped by the Tiber were already blocking the original harbor, and building a delta out to sea at nearly 1 meter (3.3ft) a year. Under Trajan (AD 98–117) navies quarrying into the alluvium dug out an artificial hexagonal basin connected by canals to the river and to the Claudian harbor. But, eventually, both harbors silted up and the shoreline advanced 5 kilometers (3mi) westward. Today Rome Airport partly covers the site of these ports.



Left: The offshore remains at Caesarea on the coast of Israel. The site is dominated by the arc of masonry collapsed from the massive breakwater which encircled the artificial harbor.

Above, right: A plan of the Claudian and Trajanic ports at Ostia, the ancient port of Rome. Superimposed over them is the modern road system under which they now lie. The aerial photograph (below, right) taken before these modern developments, shows how the mouth of the River Tiber has pushed forward the coastline since Roman times. The lines of successive coastlines can be clearly seen within the coastal dunes. The Roman harbors lay buried at center-right of this photograph.



Apollonia, a model harbor

Apollonia on Libya's northeast, or Cyrenaic, coast is a textbook example of an ancient harbor, and by chance it was the first that I explored. In 1958 my team of divers from Cambridge University discovered a wealth of buildings and other structures that have served as a touchstone for my studies ever since.

Tradition places the city's foundation in 631 bc. There are few detailed references to it in classical literature, since it was only the port for Cyrene, a big inland city that took all the local historical glory. Today Apollonia is ruined and much lies 2.0–2.5 meters (6½–8ft) under water. The site is similar to many on the Levant coast farther east. A sandstone ridge produces reefs and islands 200–250 meters (650–820ft) offshore, but forms promontories where it clips the shoreline. From west to east, the so-called Grotto Reef, West Island, and East Island all played important roles in harbor construction. Greek colonizers connected the western end of the city wall to the Grotto Reef with a rubble embankment, then built a freestanding rubble breakwater between the reef and the West Island. This created a bay with the mainland forming the southwest and south, and the mouth facing east. This mouth was narrowed by a broad wall of dressed masonry, possibly on a broader rubble foundation, built from the mainland northward toward the West Island.

The rim of this harbor revealed an extraordinary range of structures. On the inner slope of the West Island lies the best preserved set of ancient slipways in the Mediterranean. All 10 are almost un-

damaged, but completely submerged in the lee of the island. Curiously, later builders eventually covered them with stone-walled houses or huts. To the west, the breakwater bridges the gap to the Grotto Reef, where extensive quarrying in ancient times has left rock masses with precise but now unknown functions. No one has yet produced a detailed map of the reef's maze of defensive works, passages, tunnels, and quarries. In the lee of the Grotto Reef lie strange parallel rock cuttings with floor recesses. They look a bit like slipways, but are quite different from those on the West Island.

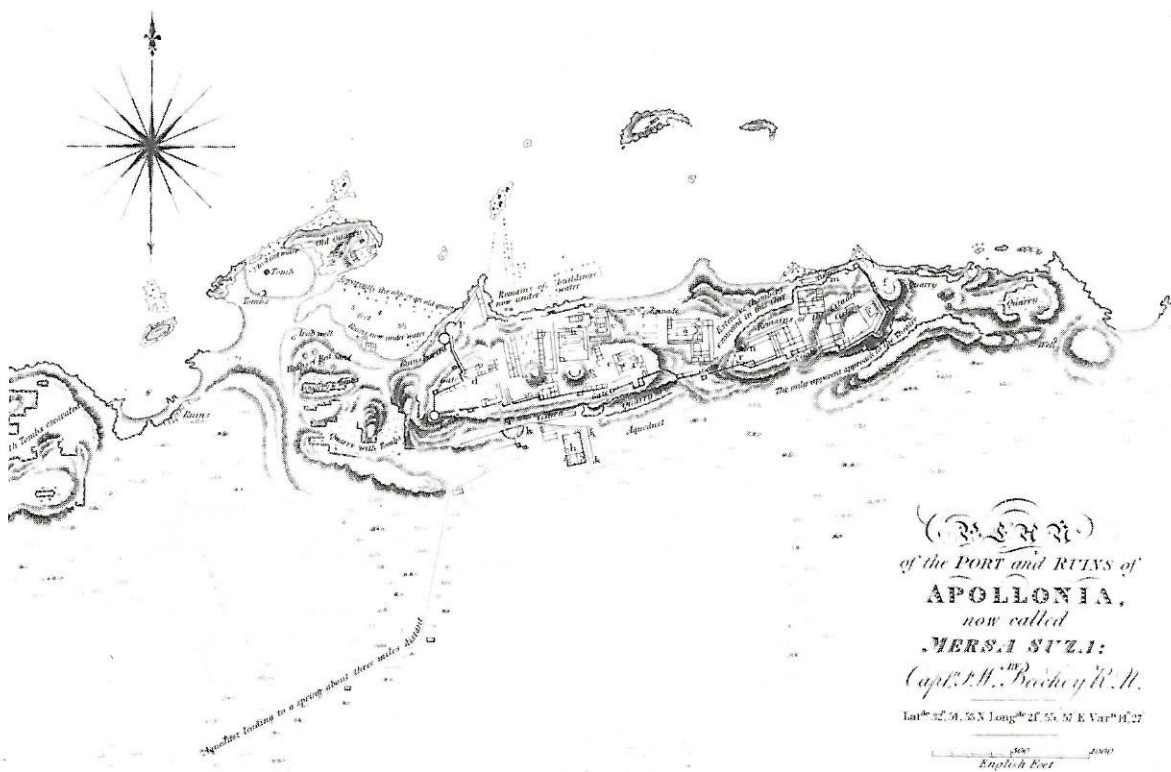
The landward side of the basin had many land-based structures: presumably storehouses, sheds, offices, taverns, "rest houses" for sailors, and so on. At one point three differently aligned layers of masonry indicate successive building periods, not yet worked out. In the southeast corner stand nine parallel quays or docks, too narrow for warships. These quays, too, pose a puzzle.

Completing the harbor circuit is a massive wall of dressed blocks, some joined with lead dovetailed dowels. This wall runs from the mainland out to the entrance. The entrance itself is a long narrow channel, flanked by and guarded by two solid towers of stepped masonry. It would have been easy to defend such an entrance, since any enemy ship trying to break into the harbor would have had to pass between rows of defending troops. So much for this harbor. But exploration revealed a great deal more. On the seaward face of the West and East islands divers found that the rock had been

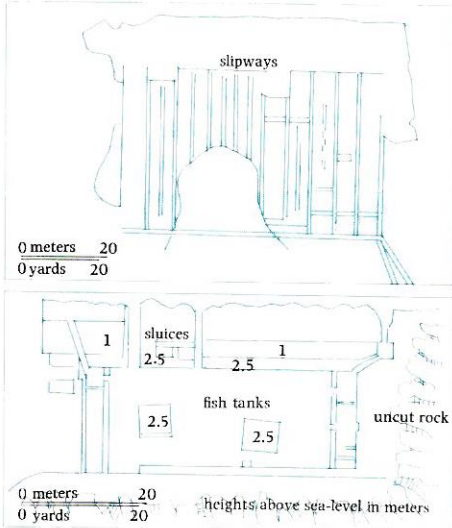
quarried to leave residual barriers 10–20 meters (33–66ft) out from the cliff to make wave traps. These wave traps still work, in spite of the change of sea level. Similar structures from the Levant suggest that the Phoenicians may have had a part in Apollonia's construction.

Outside the harbor a rubble breakwater blocked the gap between the islands, and the foundations of a large round tower on the East Island suggest that a lighthouse stood there. From the eastern end of the city a large breakwater runs north, almost out to the "lighthouse." Between them, the two breakwaters enclose an outer harbor basin of uncertain date. The outer end of the second breakwater is now in 8 meters (26ft) of water, and huge squared blocks scattered nearby on the sea floor suggest the remains of a large tower guarding the entrance.

At the foot of the mainland's acropolis hill, and just inside the landward end of the eastern breakwater, divers discovered a well-preserved piscina, or fish tank. The pool measured 50×20 meters (164×65ft) and had dividing walls, multiple channels, and sluices to control the water flow; a bordering pathway; a flight of steps; and little artificial islands presumably connected to the sides by wooden catwalks. In 1959 we found a marble statue of a faun buried in the sand, confirming the literary evidence that piscinae were liberally decorated. About 40 piscinae have now been discovered around the Mediterranean, and there are presumably many more. In the shallow water between the piscina and the central masonry



A plan of the city of Apollonia drawn up by Captain F. W. Beechey of the Royal Navy in 1827, showing the offshore remains in general terms, and indicating that in some places fewer remains were under water at that time. Opposite: A plan of the ruins now visible both above and below water at Apollonia. On the basis of this evidence, maps have been drawn to show the disposition of structures around the harbors in 200 BC and AD 600 (above, left and right).



Left: Detailed plans of some of the constructions at Apollonia; these include slipways for warships (upper) and a complex fish tank (lower).

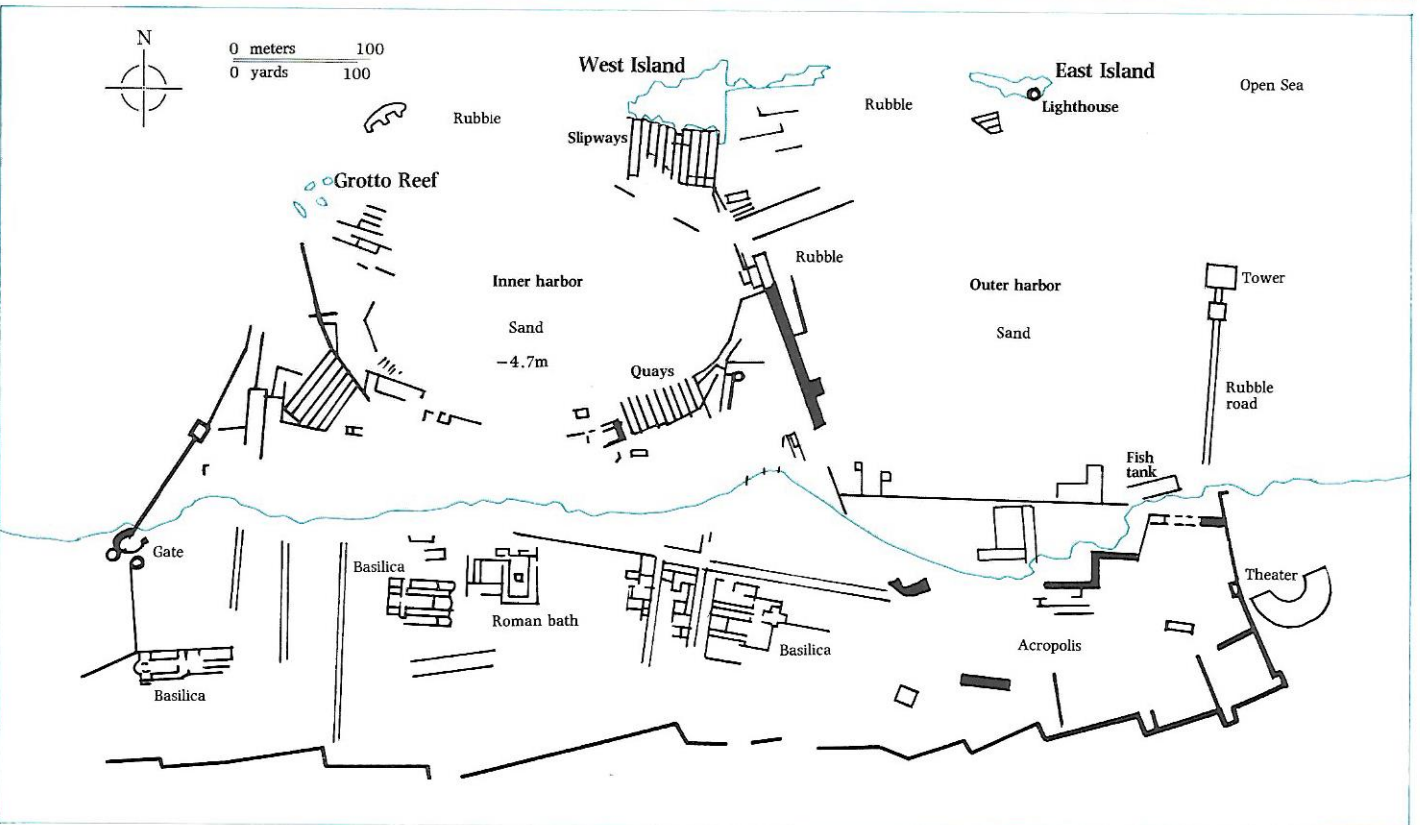
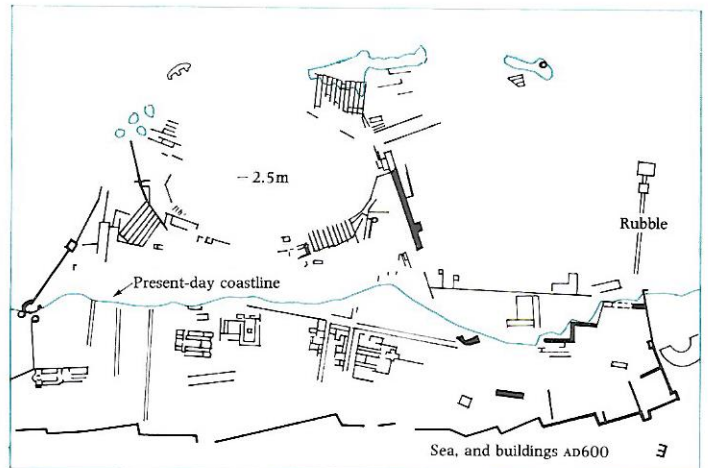
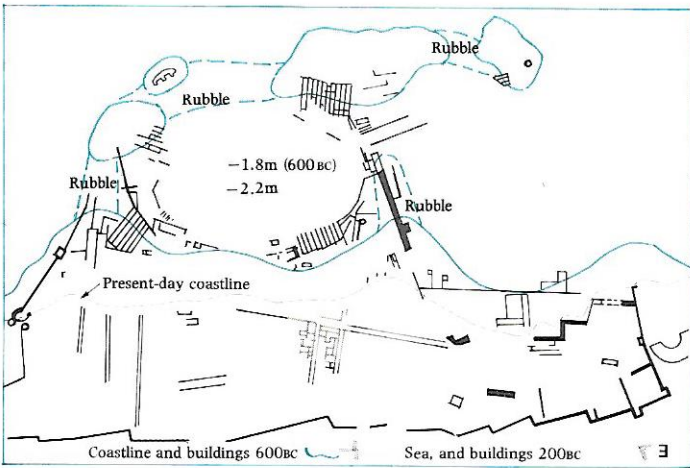
breakwater are relics of numerous land-based buildings, including beehive-shaped grain-storage silos cut into the rock. Silos like this are common near the waterfronts of other ancient Greek ports, and crop up as far apart as Syracuse in Sicily and Kas in Turkey.

The small buildings overlying the slipways, and the superimposed warehouses and apsidal buildings on the southeast side of the inner basin, suggest there were several periods of reconstruction at Apollonia, during which the two basins considerably changed in appearance and use. As ships grew bigger, and the grain trade with Rome became all important, the outer basin emerged as the commercial center, while

the inner basin sank to the status of fishing harbor.

Studies of present and past water depth at different places give paradoxical findings. The slipways were almost certainly built centuries earlier than the piscina, and yet are submerged less deeply. One can only conclude that earth movements have tilted the site, or that the sea level was relatively lower when the piscina was built, which is just possible.

Apollonia was revisited by Bob Yorke and David Davidson in 1972 during a survey of other ports in Cyrenaica. The more we learn about other harbors and ports around the Mediterranean, the more clearly we see that Apollonia is exceptionally well preserved. A really thorough survey there today might answer dozens of questions that we were in no position to ask in the 1950s.



Harbors and sea-level changes

We end this chapter with a broad look at the distribution of Mediterranean ports in their classical heyday and at their subsequent patterns of uplift and sinking.

Between them, the Mediterranean and Black Sea held about 1,000 active harbors in Roman times. For the Mediterranean's western basin that meant on average one harbor for every 35–45 kilometers (22–28mi) of coastline. If we ignore barren stretches, the figure was one every 18–25 kilometers (11–15½mi). In the eastern basin the Aegean's hundreds of harbors rimmed the convoluted coasts of a small sea at an average interval of only 15–20 kilometers (9–12mi). The shores of what are now southern Turkey and Israel had a similar density. But Bronze Age Israel had had coastal settlements only some 10 kilometers (6mi) apart, and by Roman times, the number of active harbors in the Levant as a whole had fallen. The North African coast from Alexandria to Leptis Magna was the stretch least well endowed with Roman

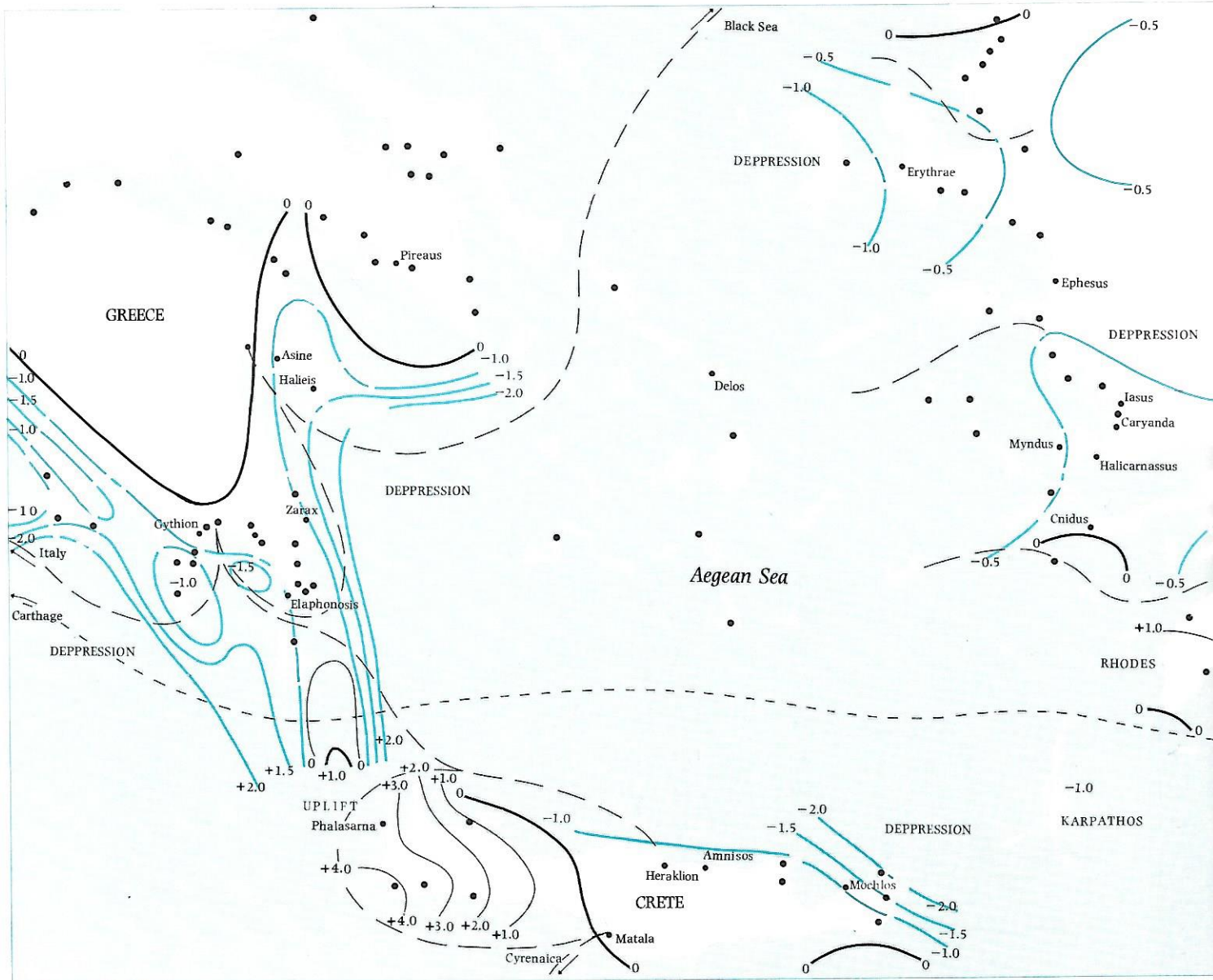
or indeed other early ports. In the Gulf of Sirte coastlines hundreds of kilometers long show nothing worth calling a port. This is largely due to the sandy, unproductive hinterland; shallow, sandy, coastal waters; and onshore winds dangerous to shipping. In contrast, the hilly and mountainous country of Cyrenaica was then very fertile and rich. Cyrenaica's shores held most Roman ports of eastern North Africa.

In Roman times builders left less of a mark around the Black Sea than around the Mediterranean. There were probably 10–20 major ports in the 1,000 kilometers (620mi) of northern Black Sea coastline. However, the southern shore was fairly well developed.

The amazing upsurge of Roman port building and modernization between about 100 BC and AD 100 proves that ports played a vital role in the success and stability of the empire. Trade, administration, and troop movements all relied on a network of sea routes served by ports kept safe from weather and piracy. Emperors and provin-

cial administrators clearly recognized this, and harbors were prestigious structures, laden with civic and religious symbolism, and planned with care. The standardized building techniques used for harbors throughout the Mediterranean tempt us to guess that Rome had a corps of harbor engineers, rather like the US Army Beach Erosion Board. Also, so many big harbors were built in so short a time that we can hardly credit them to a few brilliant individual designers. We must assume that the "Roman Navy Harbor Board" had training establishments and manuals of engineering methods, and that Rome could deploy or hire out trained engineers and their key assistants anywhere in the empire.

Since the Mediterranean has so many ancient harbors, and since we largely know when these were built and used, they form a unique set of evidence for ancient sea levels and earthquakes. The British marine archaeologist David Blackman and others have shown how the original sea



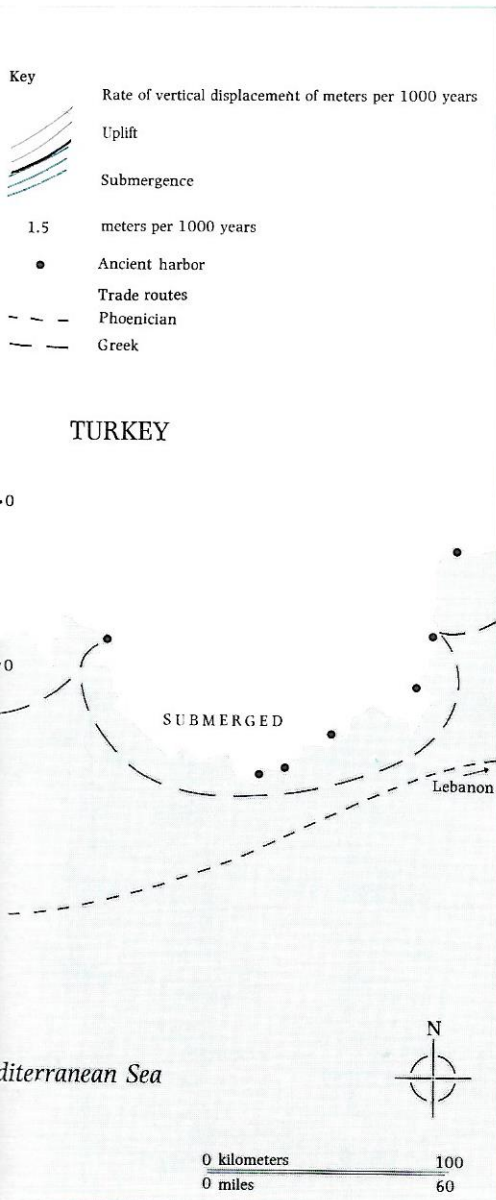
level can be derived from structures such as slipways, quays, mooring stones, fish tanks, and salt-pans. If tidal and atmospheric effects are measured carefully as well, the relative change of sea level at a site can be determined with a probable error of sometimes only 25 centimeters (10in), or more usually 50 centimeters (20in).

Since the mid-1950s, archaeologists have studied the relative change of sea level at hundreds of old Mediterranean harbors. This means that we can show how fast and far change has happened all around the coast since Roman times. Unfortunately, we lack reliable data for other periods except for the Aegean and the eastern shore from Syria to Egypt. These areas also contain significant remains from preclassical, Byzantine, and medieval times. Interpreting the measurements is not so easy as it might appear. There is a statistical problem in separating worldwide, or eustatic, change of sea level from local or regional earth movements or tectonic changes. Without

plunging into any mathematics, we can see that a eustatic change would have been identical in timing and extent for every site, while tectonic changes would have varied from one site to another. It is possible to program a computer to separate one type of change from the other. Even so, the uniform, or synchronous, factor may actually include a steady regional tectonic change indistinguishable, within the limits of the observations, from a eustatic change. Thus any attempts to identify a truly worldwide sea level curve is frustrated. (See also pp. 132-37.)

In the Mediterranean it turns out that the areas of submergence and uplift are quite restricted, while long stretches of coast show no relative movement at all during the last 5,000 years. Also, rather unexpectedly, submergence is much commoner than uplift. In the western basin, submergence has affected the Bay of Naples, southern Sardinia, southeast Sicily, Carthage, and the area around modern Algiers. Of 179 cities,

26 are submerged and two show uplift. Studies of the eastern basin are incomplete; in particular the Adriatic, north Aegean, and Egyptian coasts have not been investigated. In the south Aegean, south Turkey, and Cyprus, of 175 ruins with dated levels 100 show submergence, 43 indicate definite stability, and 32 indicate relative uplift. This last group is concentrated in the islands of the Cretan arc. The south coast of Turkey from Antalya to the Orontes is extremely stable. The coasts of Syria and Lebanon show irregular submergence. Most Israeli sites are stable, but 61 show submergence, and three sites show movements up and down. To conclude, geological and oceanographic theories can help to explain why the levels of the sea and land change as they do, but local effects are so unpredictable that every archaeological site must be treated strictly on its merits. The local evidence for submergence or uplift must be investigated objectively and believed, even where it clashes with cherished theory.



Left: A contour-map of the Aegean area. The lines join together locations that have been subject to the same degree of lifting or lowering over the past 2000 years.

Above: Some areas have emerged from the sea rather than been drowned. The rock cuttings an Zinibull (above) are typical of such change - the blue tint indicates the maximum sea level in classical times. A similar situation can be seen with the tombs at Matala (right).

